Review of Plutonium Attribute Measurement Technologies: Gamma-Ray and Symmetry Measurements

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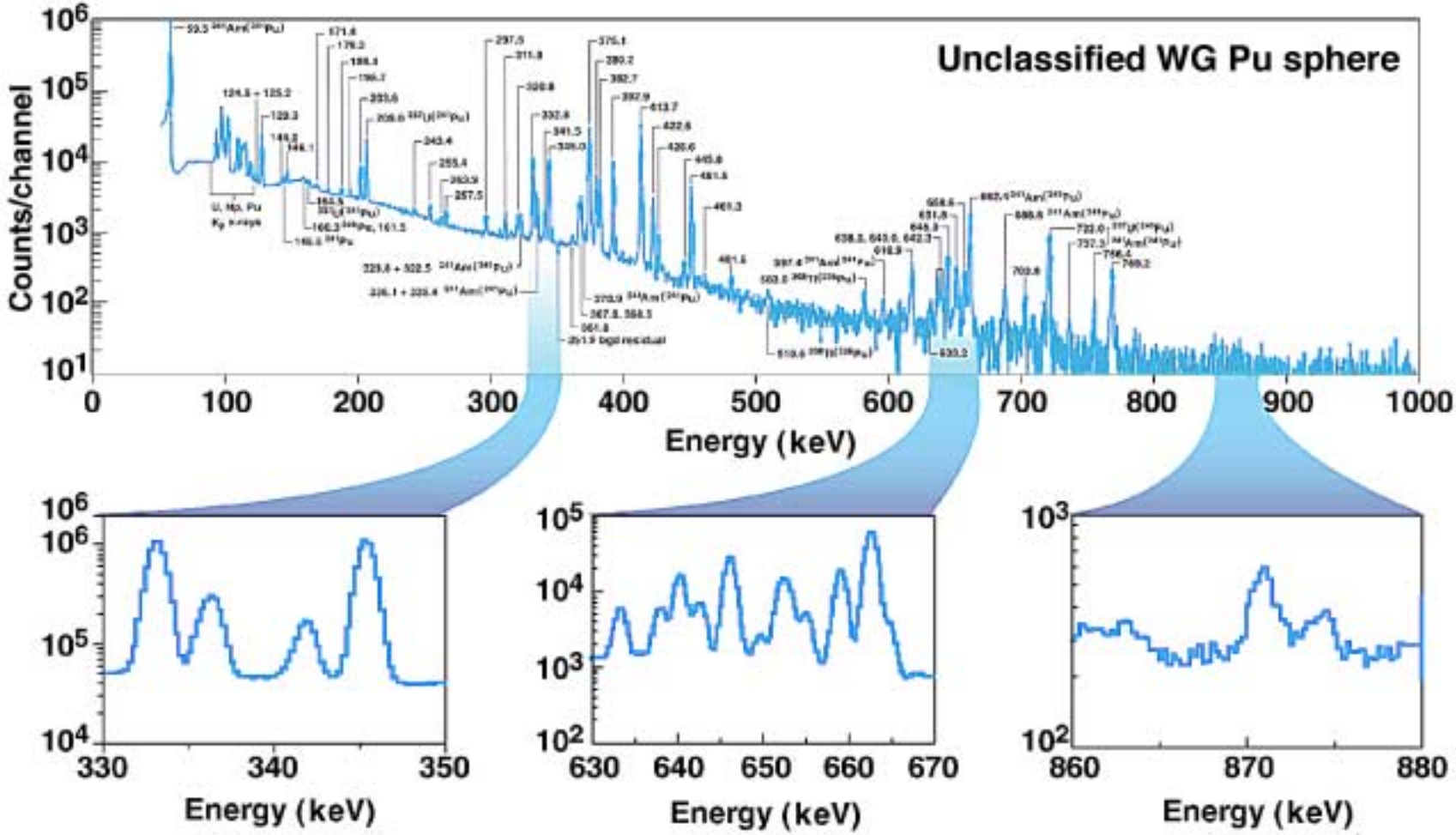
What This Talk Will Cover

Attributes	Methods	Sensors
Plutonium age Presence of Pu	Pu-300	High-purity Ge (50%)
Presence of Pu Presence of WG Pu	Pu-600	
Absence of PuO_2	Pu-900	High-purity Ge (100%)
Symmetry	nSymmetry	Neutron singles detectors

Gamma-Ray Methods

- Elements common to each of the gamma-ray measurements
  - Collect only the data required
  - Measurement geometry
  - Source and geometry independence
- Elements specific to each of the gamma-ray measurements
  - Pu-300
  - Pu-600
  - Pu-900

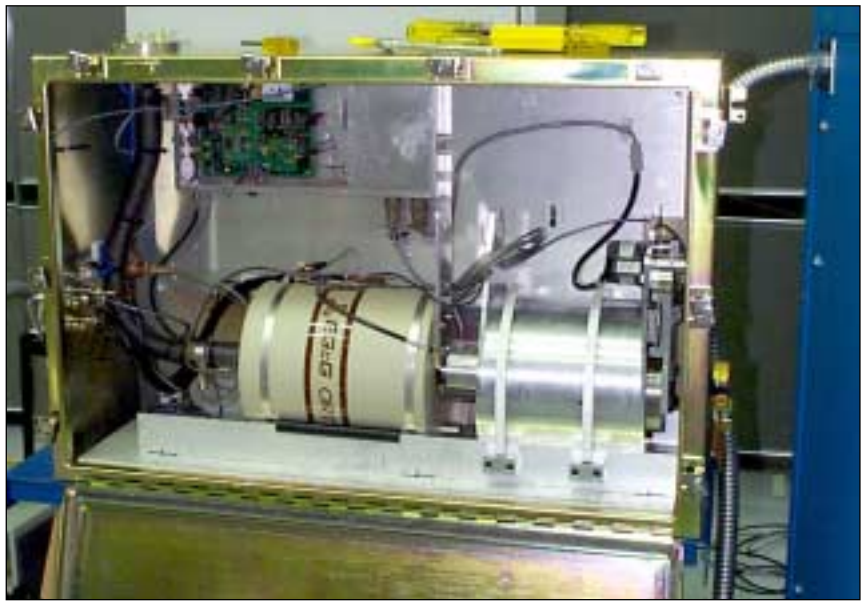
Collect Only the Data Required



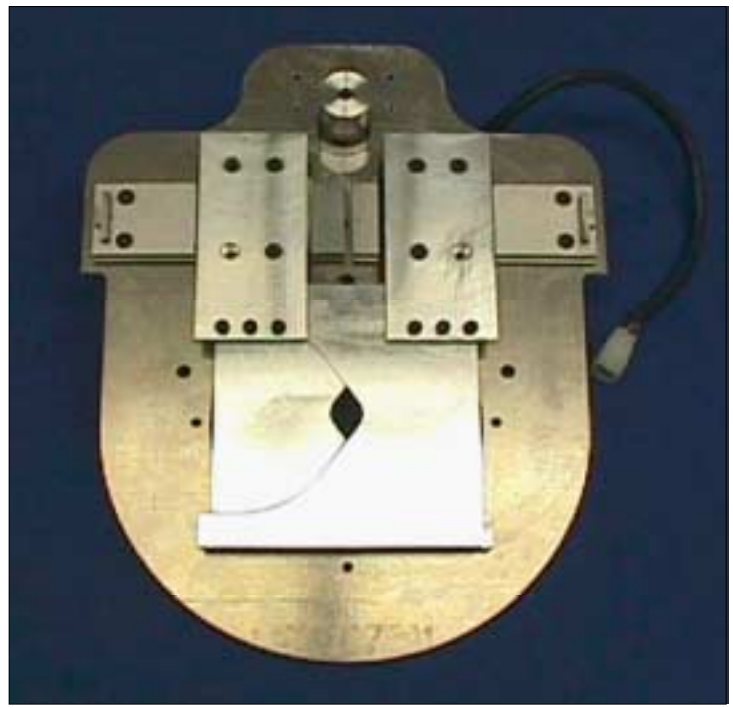
Gamma-Ray Measurement Geometry

Both the Pu-300/600 detector and the Pu-900 detector view the source through the neutron multiplicity counter (NMC).

Source and Geometry Independence



> To achieve this independence we:
- Fix the source/detector distance
- Fix the counting interval



We do this by: <
- Employing a massive shield
- An autonomous tungsten iris
  - Optimizes count rate
  - Shrouds the counting geometry

Why Use Two Gamma-Ray Detectors?

- **To save time—to make the measurements in narrow energy bands, three separate measurements must be made.**

Detector 1

The Pu-300 and Pu-600 measurements are made serially

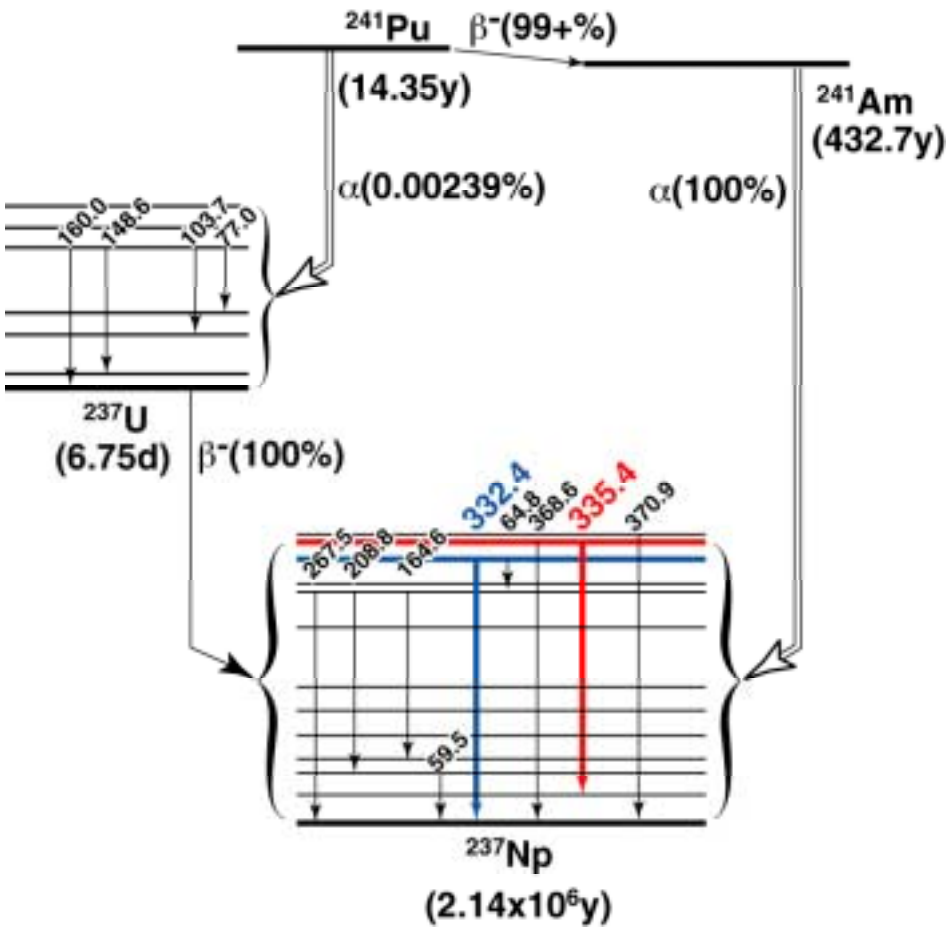
Pu-300 (age attribute)
Pu-600 (weapon-grade attribute)

Detector 2

Simultaneously, the Pu-900 measurement is being made

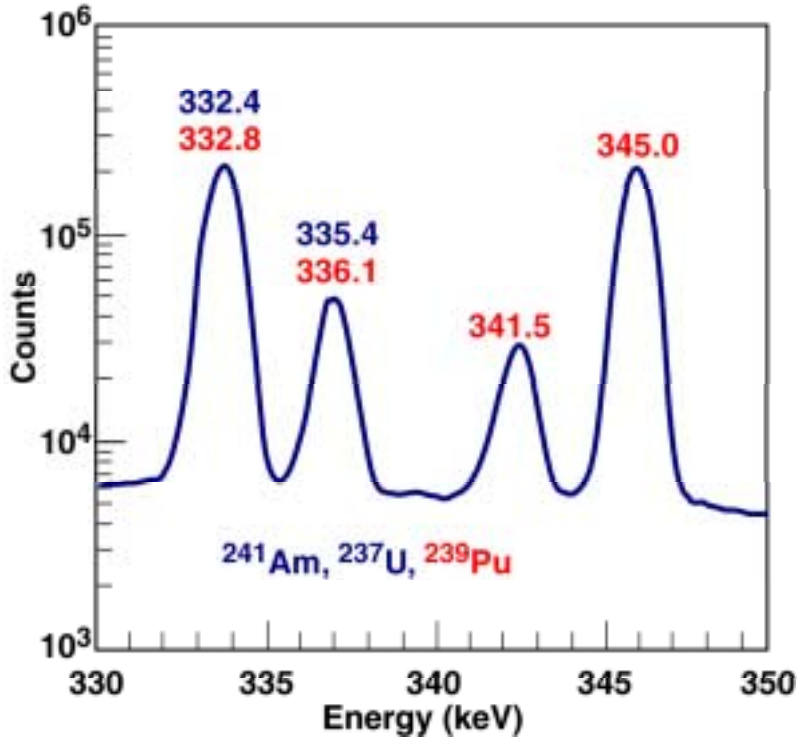
Pu-900 (absence of PuO_2 attribute)

Pu-300—Plutonium Age / Presence of Pu



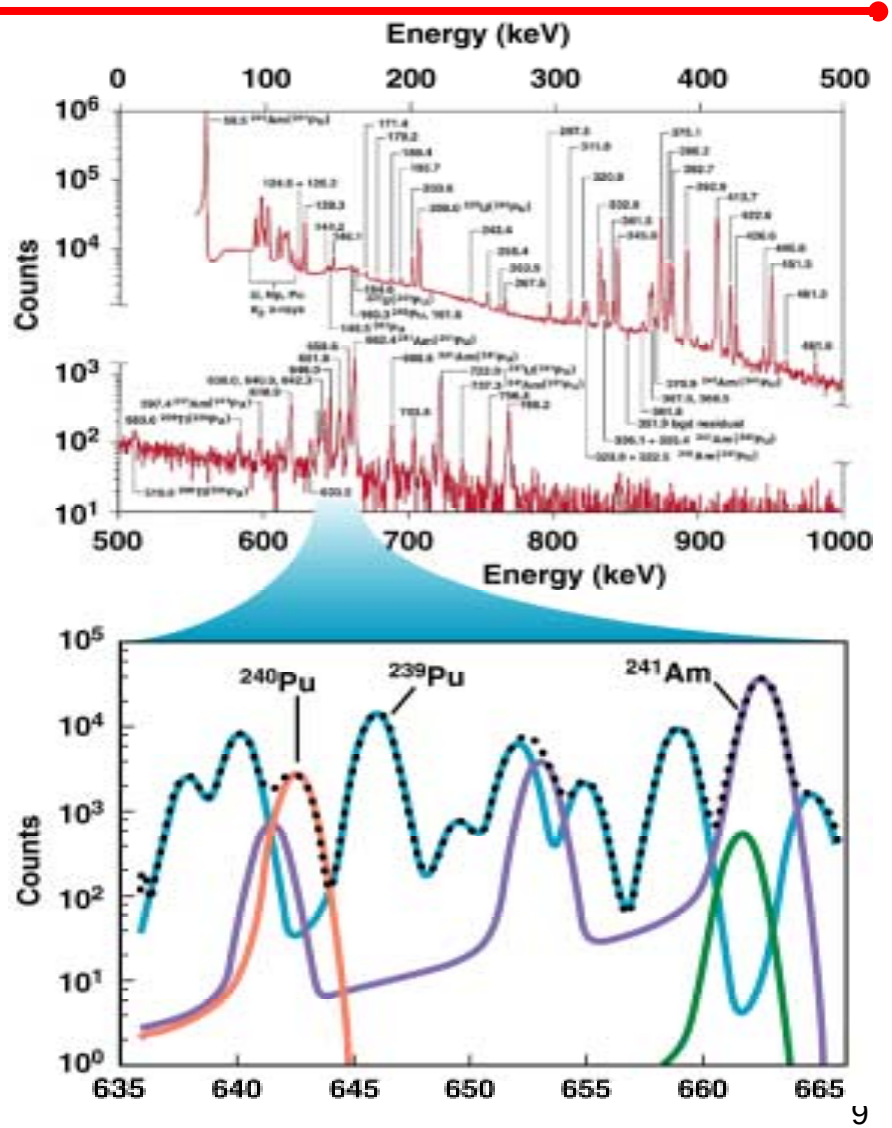
- Presence of Pu indicated by the 345.0 keV ^{239}Pu line.

- Pu age since separation determined by the ratio of ^{241}Am to ^{241}Pu.
- The ratio of the 332.4 and 335.4 keV lines is a function of time because they are populated at different rates in the two decay branches.



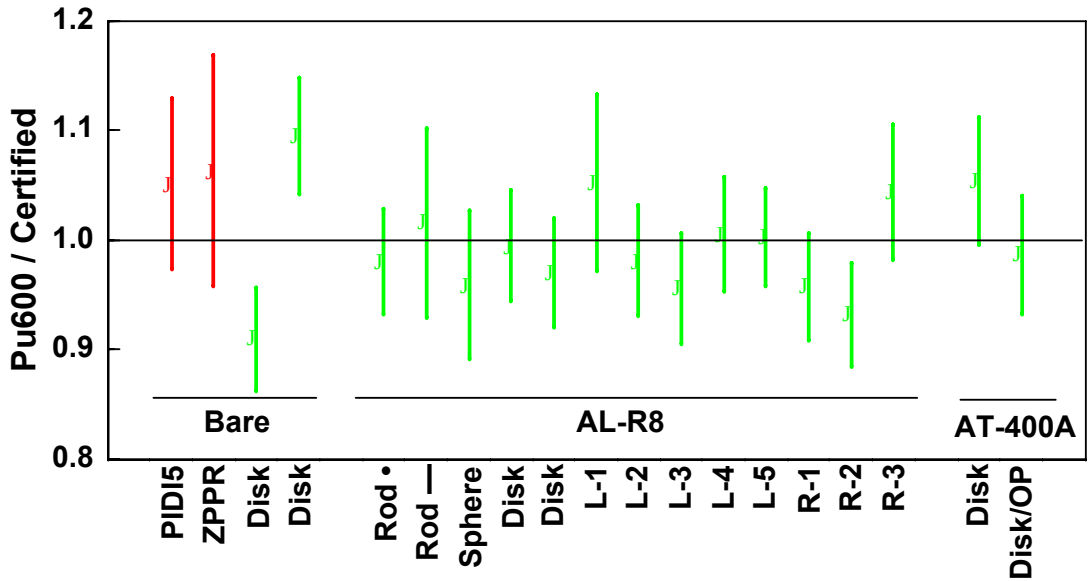
Pu-600—Weapons-Grade Pu / Presence of Pu

- **Weapons-grade plutonium:**
  - For weapons-grade plutonium: $^{239}Pu + {}^{240}Pu \approx$ Total Pu.
  - Therefore, if the ratio $^{240}Pu/\ ^{239}Pu$ is low, the material is weapons-grade.
  - This value is also used in conjunction with the neutron multiplicity data to determine the plutonium mass.
- **Presence of plutonium:**
  - 646 and 659 keV peaks.
  - Determination of presence requires *both* the 345 keV peak from Pu-300 and the 646 and 659 keV peaks from Pu-600.



Weapons-Grade Pu Presence in Storage Containers—Pu-600 Method Measures $^{240}Pu/^{239}Pu$ Ratio

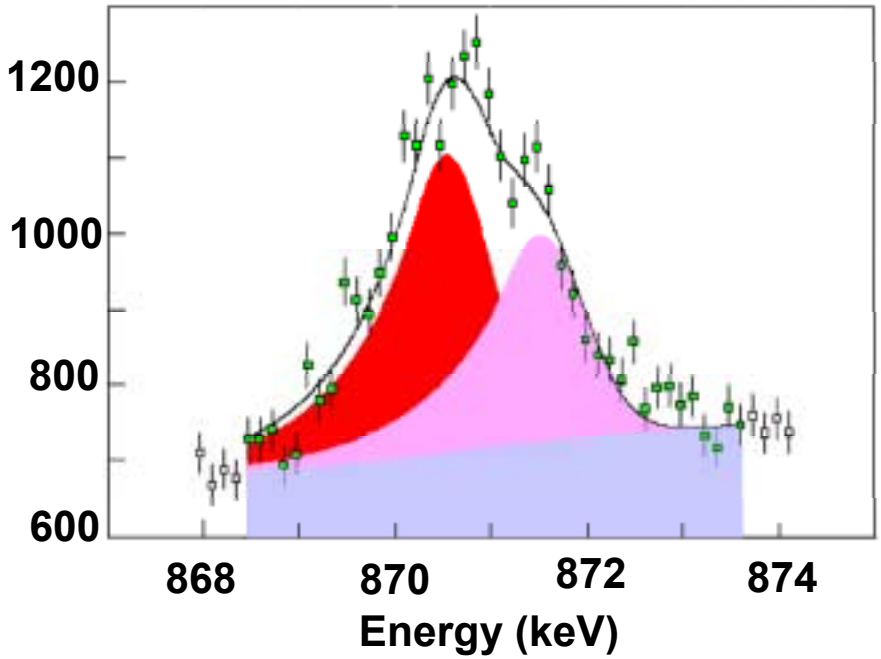
- Uses commercial equipment
- A variant of MGA plutonium isotopics code
- Successfully tested against a variety of Pu objects in various types of containers



Successfully tested against a variety of Pu objects in various types of containers

Pu-900—Verify Absence of PuO_2: A Work in Progress

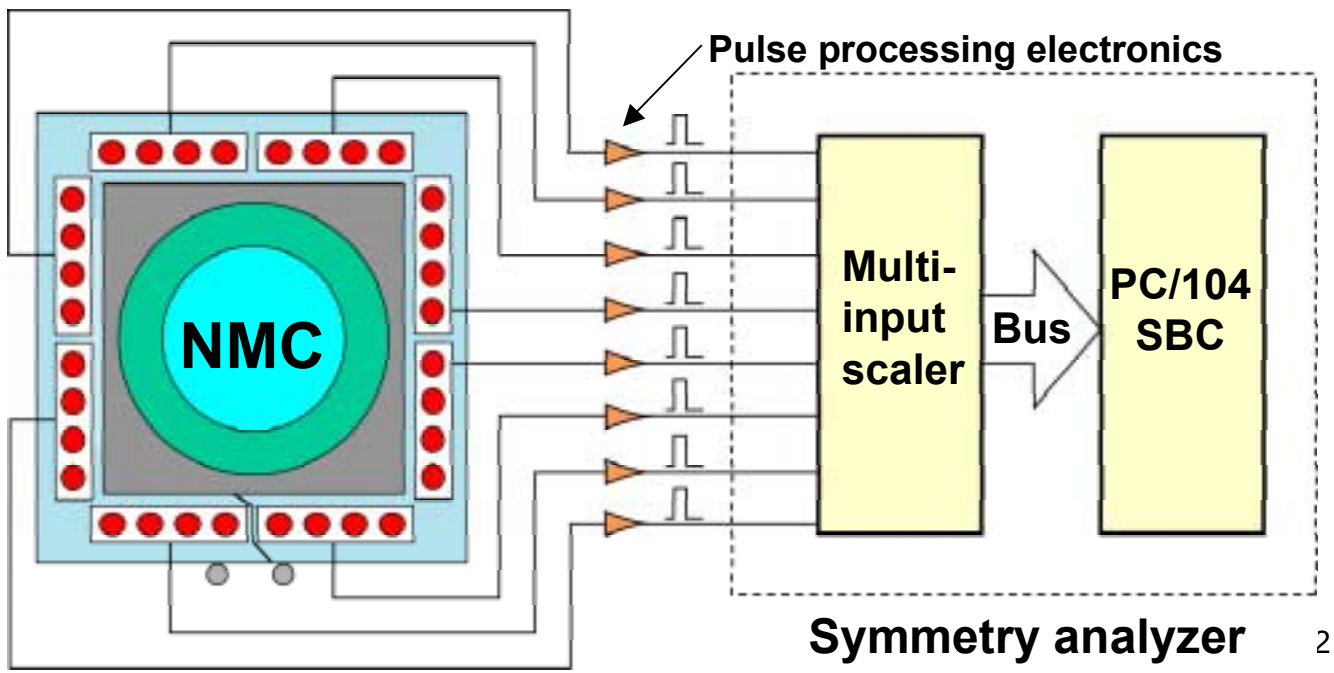
- We use the 870.8 keV gamma ray from the first excited state of ^{17}O as an indicator of the presence of PuO_2.
- The source of this gamma ray is somewhat ambiguous.
  - It is known to arise from coulomb excitation (α,α'), likely due to alpha decay of ^{239}Pu.
  - It may also be due to an (α,p) reaction from nitrogen impurities.
  - Experiments to resolve this ambiguity are underway.
- Our experience shows that this peak is always present in PuO_2 and not present in Pu metal.



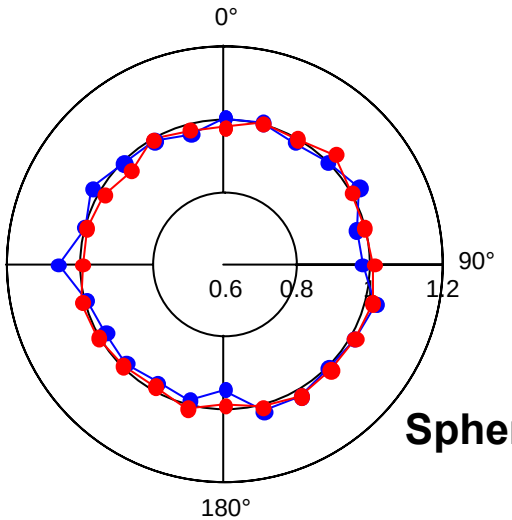
- A shoulder peak is sometimes observed and is easily resolved.
- The origin of this peak is also under investigation.

Neutron Method for Measuring Symmetry

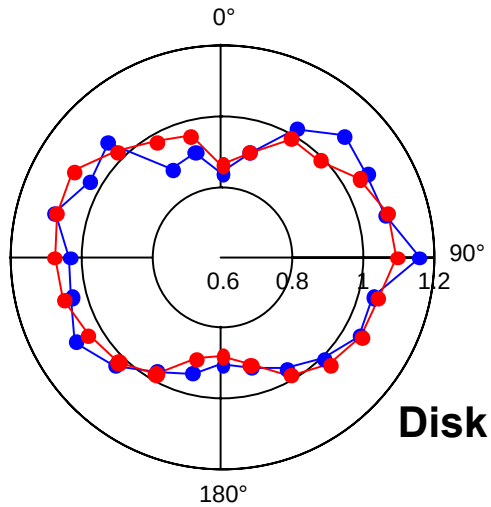
- Under some circumstances, it may be important to know if the object in a storage container is cylindrically symmetrical.
- We test for cylindrical symmetry as indicated by an isotropic neutron radiation field:
  - —suggested by the Russian Federation at Moscow talks in 1996
  - —US/Russian Federation experiments tested the method at LLNL in November 1996.



Cylindrical Symmetry as Indicated by an Isotropic Neutron Radiation Field



Sphere



Disk

- **Ideally, if the item is cylindrically symmetrical, the neutron counts in all detectors will be equal.**
- **We test for a significant variation from equality:**

$$s = \max\left(\frac{|y_i - \bar{y}|}{\bar{y}}\right), \qquad \sigma_s = \frac{\sqrt{y_i}}{\bar{y}}$$

- **To fail the symmetry test, both s and s/σ_s must be large (>0.15 and >3).**